

教育部「5G行動寬頻人才培育跨校教學聯盟計畫」
5G行動網路協定與核網技術聯盟中心

Mobile Edge Computing: 行動邊緣計算

實驗單元-03：VoD Streaming 資料串流實驗

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國立高雄科技大學 電腦與通訊工程系

Outline

- 實驗目的及實驗內容
- 實驗環境
- 平台安裝需求
- Cloud與Edge伺服器的通訊協定
- Cloud、Edge程式碼修改
- VoD Streaming資料串流實驗執行
- 附錄

實驗目的

- 使用 MEC 平台實作多媒體影音串流的 Service Migration。
- 使用 UE 與網頁伺服器測試影音串流的特性。

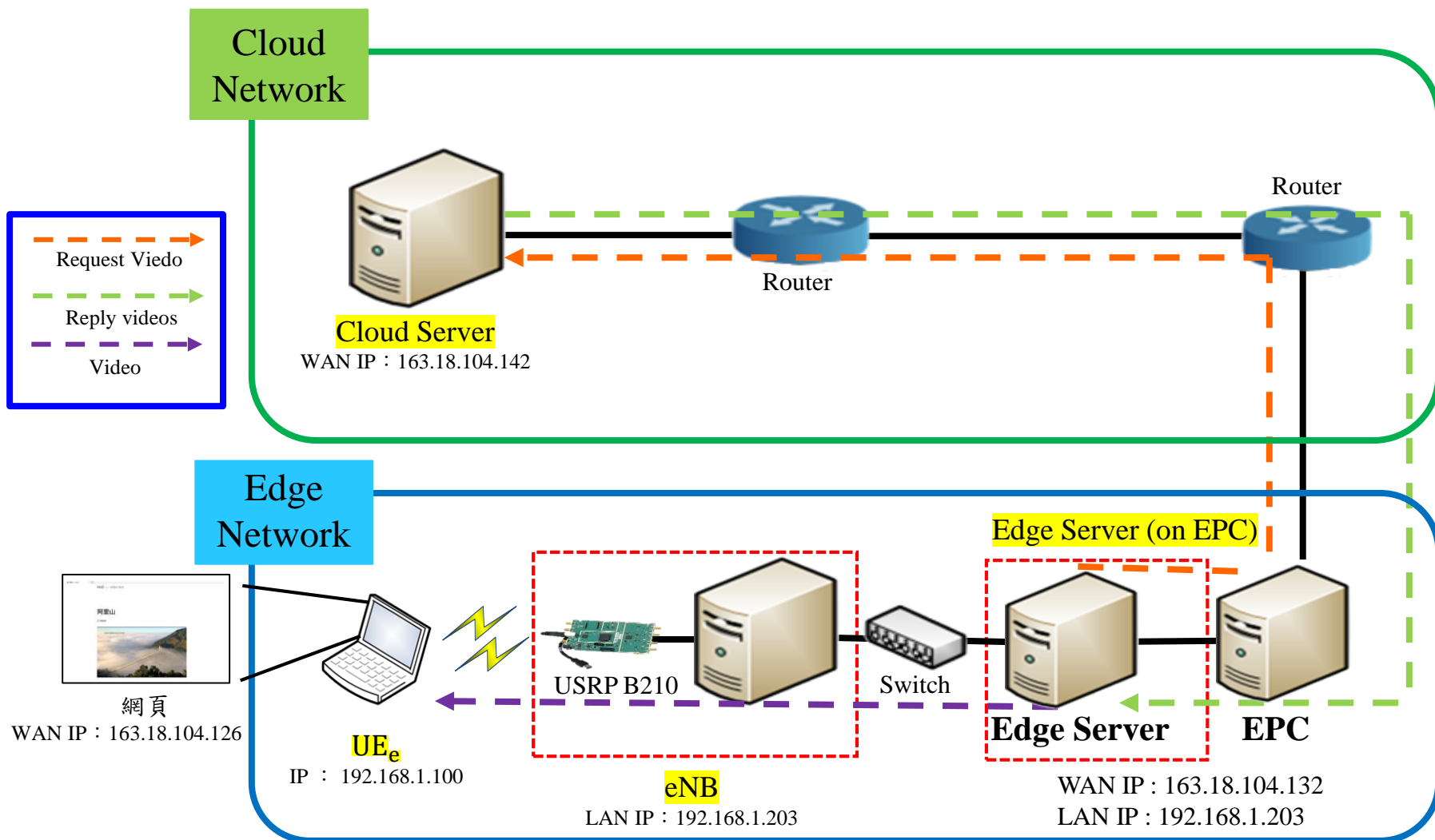
實驗內容

- 了解Cloud與Edge的影音串流通訊協定
- VoD Streaming 資料串流實驗

Outline

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實驗架構



實驗設備-硬體(1/2)*

名稱	硬體	數量	目的
Cloud Server	CPU : i7-6500U RAM : 8 GB HDD : 1 TB	1 台	儲存影片
	Ethernet Network PCIE Card	1 個	連接WAN (for Internet)
Edge Server	CPU : i7-8559U RAM : 8 GB HDD : 1 TB	1 台	將Cloud Server的熱門影片， 傳送至Edge Server
	Ethernet Network PCIE Card	1 個	連接WAN (for Internet)
	RJ45 外接網卡 (USB)	1 個	連接LAN (for eNB)
eNB	CPU : i7-8559U RAM : 8 GB HDD : 1 TB	1 台	eNodeB 基地台
	Ethernet Network PCIE Card	1 個	連接EPC的LAN
	USRP B210	1 片	接收 eNB 封包資料，轉成 LTE訊號發送
	VERT2450 Antenna	2 支	收發 LTE Band 7 (2600 MHz) 訊號
	USB 3.0 cable	1 條	連接 eNB 與 USRP B210

實驗設備-硬體(2/2)

名稱	硬體	數量	目的
Web Server	CPU : i5-3470 RAM : 8 GB HDD : 500 GB	1 台	提供UE到網站上觀看Cloud Server 與 Edge Server的影片
	Ethernet Network PCIE Card	1 個	連接WAN (for Internet)
UE	CPU : i7-9750H RAM : 8 GB SSD : 256 GB	1 台	連接eNB
	4G Dongle	1 個	提供電腦使用行動網路
	LTE SIM卡	1 張	提供UE使用，跟EPC註冊
Switch	4-port switch (legacy)	1 台	LAN互相連接
RJ45雙絞線	RJ45雙邊接頭的CAT 5e網路線	5 條	Edge*2條、eNB*1條 Cloud*1條、Web Server*1條

實驗設備-軟體

名稱	軟體	版本
Cloud Server	OS : Ubuntu	16.04 LTS
	Nginx	1.5.0
	C語言	5.4.0
Edge Server	OS : Ubuntu	16.04 LTS
	OAI-EPC	https://gitlab.eurecom.fr/oai/openair-cn.git (發布日期:2017/3/31)
	Nginx	1.5.0
	C語言	5.4.0
eNB	OS : Ubuntu	16.04 LTS
	OAI-eNB	https://gitlab.eurecom.fr/oai/openairinterface5g/tree/17b9a9e917ce2a3a8c7004c7b9a221c350ddfe17 (發布日期:2015/8/8)
Web Server	OS : Windows 10	1909
	WampServer	3.2.0
	WordPress	5.4.2
UE	OS : Windows 10	1909
	VLC	2.2.4

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Cloud Server 安裝需求

- Cloud Server的安裝需求(ubuntu 16.04)
 - 1.Video Streaming Server 安裝
 - Nginx，請參考實驗單元-02
 2. TCP/UDP Socket 安裝
 - C語言，請參考實驗單元-02
 - 3.Cloud程式碼
 - 程式碼 請參考附錄下載

Edge Server 安裝需求

- Edge Server的安裝需求(ubuntu 16.04)
 - 1.Video Streaming Server 安裝
 - Nginx，請參考實驗單元-02
 2. TCP/UDP Socket 安裝
 - C語言，請參考實驗單元-02
 - 3.Radio Access Network 安裝
 - OAI-LTE，請參考實驗單元-02
 - 4.Edge程式碼
 - 程式碼 請參考附錄下載

其他的安裝需求

- UE的安裝需求(windows 10)
 - 1. 影片瀏覽
 - VLC，請參考實驗單元-01
- Web Server的安裝需求(windows 10)
 - 1. 網頁伺服器
 - Wamp Server、WordPress，請參考實驗單元-01

Outline

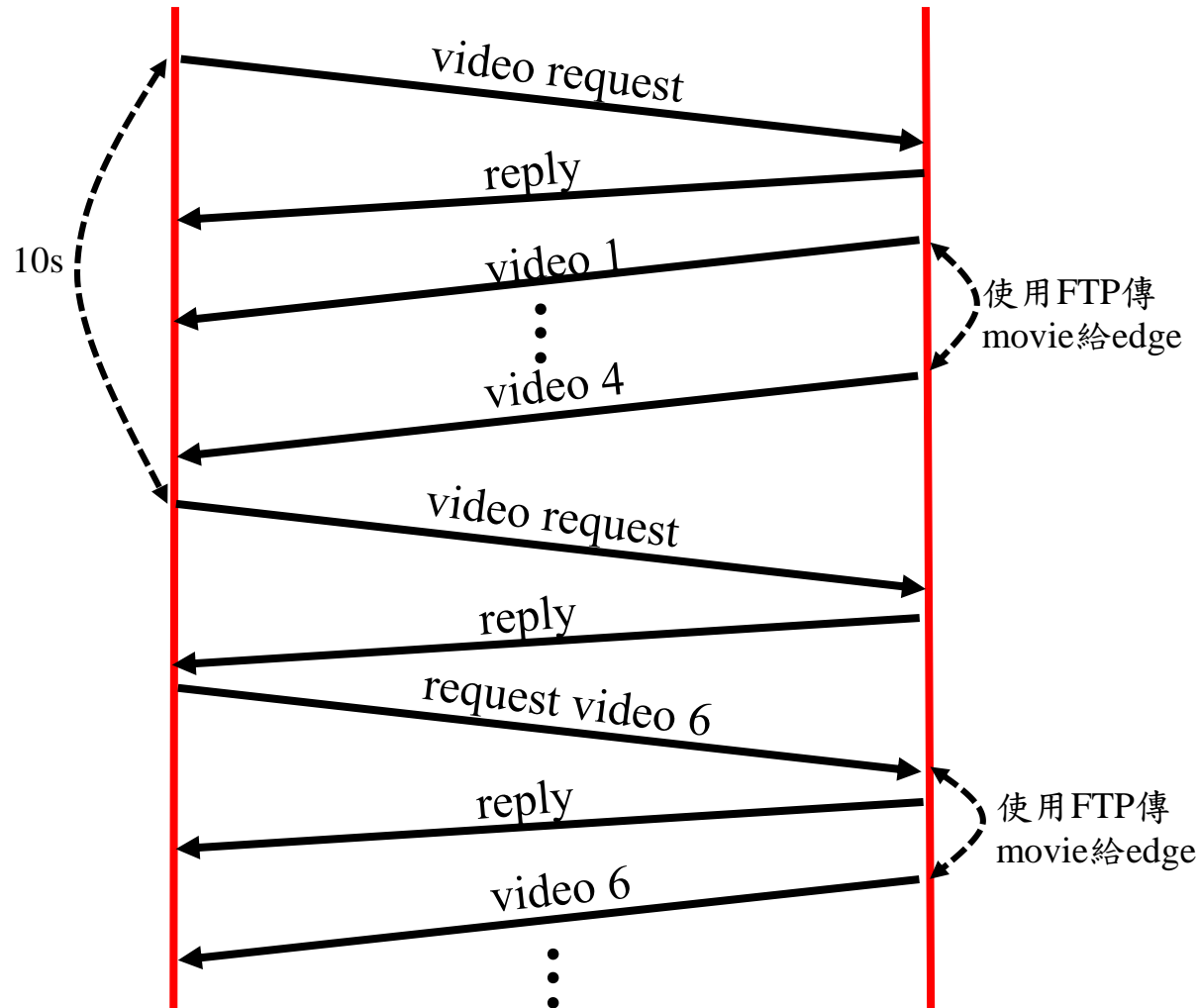
- 實驗目的及實驗內容
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Cloud與Edge伺服器的通訊協定 (1)

- Edge Server使用UDP socket定期傳送要求熱門影片訊息給Cloud server。
- Cloud Server與Edge Server之間使用TCP Socket來傳遞影片檔案。

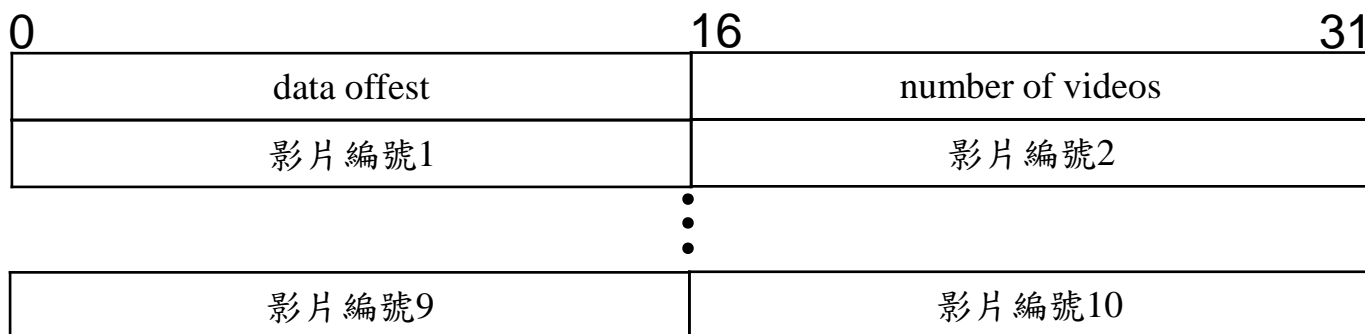
Cloud與Edge伺服器的通訊協定(2)

Edge server UDP socket cloud server

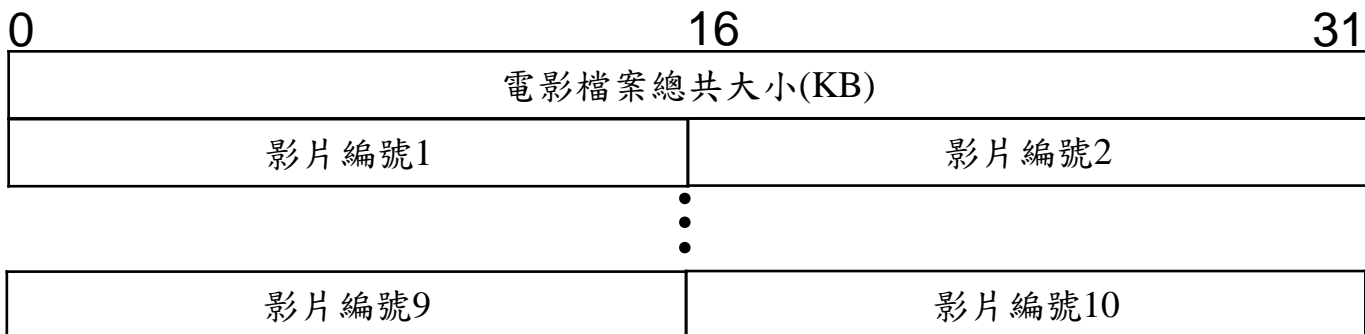


Cloud與Edge伺服器的通訊協定(3)

video request format:



reply format:



Cloud與Edge伺服器的通訊協定(4)

- Cloud Server (Server端)

```
if ((fd = open(file[a-1].name, O_RDONLY)) < 0)
{
    printf("Open file Error!\n");
    buffer[0] = 'N';
    if (write(sockfd, buffer, N) < 0)
    {
        printf("Write Error! At commd_get 1\n");
        exit(1);
    }
    return;
}

buffer[0]='Y';
if (write(sockfd, buffer, N) < 0)
{
    printf("Write Error! At commd_get 2!\n");
    close(fd);
    exit(1);
}

while ((nbytes = read(fd, buffer, N)) > 0)
{
    if (write(sockfd, buffer, nbytes) < 0)
    {
        printf("Write Error! At commd_get 3!\n");
        close(fd);
        exit(1);
    }
}

close(fd);
close(sockfd);
```

Server端:

- 1.以open函數開起所要傳送的檔案
- 2.從fd指向的檔案中讀取N個位元組資料
- 3.從buffer中讀取nbytes位元組資料，並用write函數傳送

Cloud與Edge伺服器的通訊協定(5)

- Edge Server (Client端)

```
if ((fd = open(inputbuffer, O_WRONLY | O_CREAT | O_TRUNC, 0644)) < 0)
{
    printf("Open Error!\n");
    exit(1);
}
while ((nbytes = read(sockfd, buffer, N)) > 0)
{
    if (write(fd, buffer, nbytes) < 0)
    {
        printf("Write Error!At comnd_get 2");
    }
}

close(fd);
close(sockfd);
```

client端:

1. 用open函數建立一個檔案，檔案地址從server端獲取
2. read函數獲取N位元組資料放入buffer中
3. write函數將buffer中的內容讀取出來寫入fd所指向的檔案

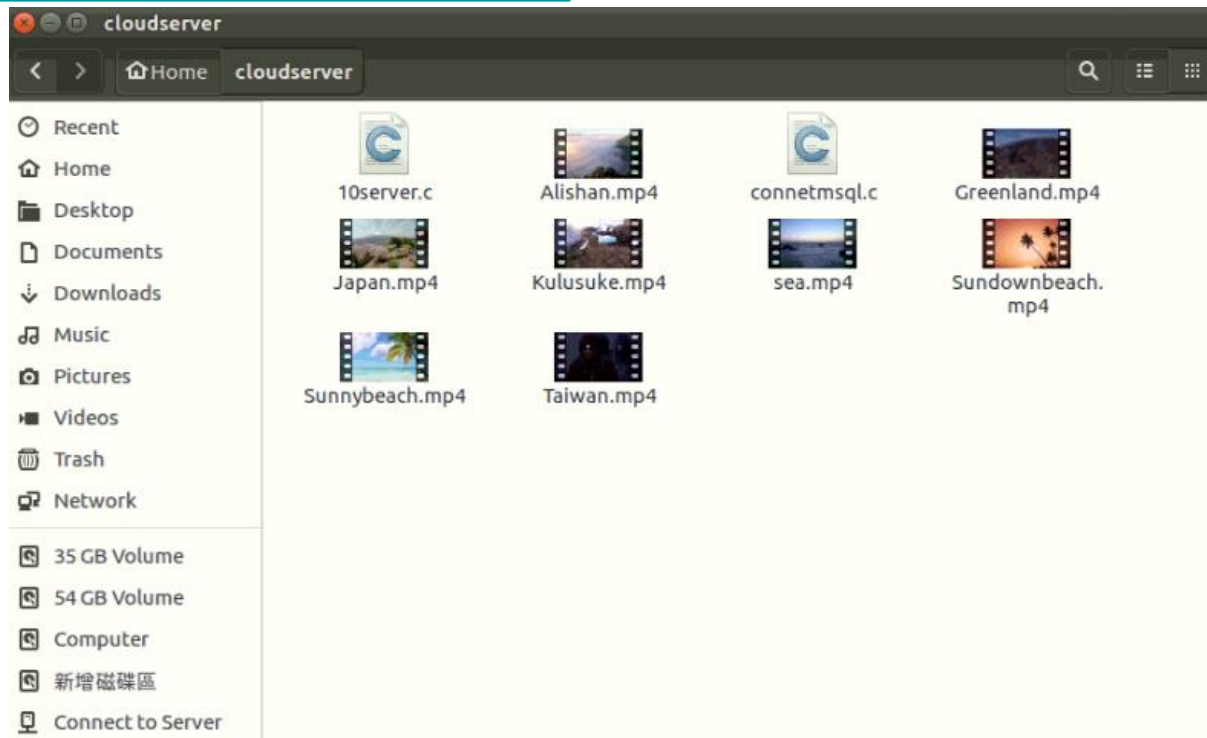
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Cloud Server 安裝

Cloud Server 程式下載

- 將cloudserver.zip下載，解壓縮後放到home目錄下
- 網址：<https://drive.google.com/drive/folders/1RJ7cxJgYCAKWl58kR-qxVLkhW8TsXNiM?usp=sharing>



設定nginx

- 在終端機輸入
`sudo gedit /usr/local/nginx/conf/nginx.conf`
- 將程式碼更改成下圖



```
worker_processes 2;
events {
    worker_connections 1024;
}
rtmp {
    server {
        listen 1935;
        chunk_size 4000;

        application myapp {
            live on;
        }

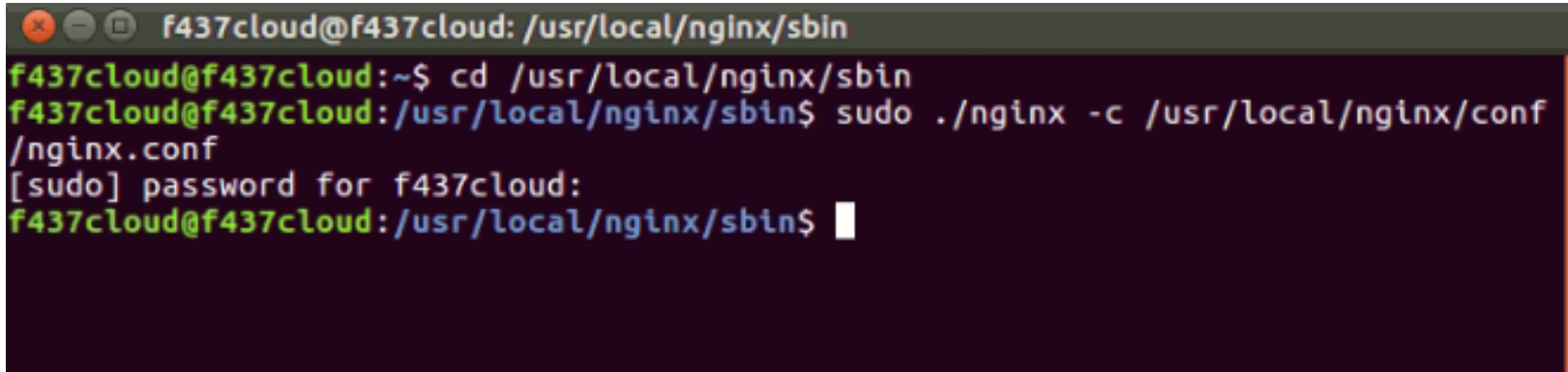
        application vod {
            play /home/f437cloud/cloudserver;
        }
    }
}
```

Cloud Server影片播放位置

開啟nginx

在終端機輸入

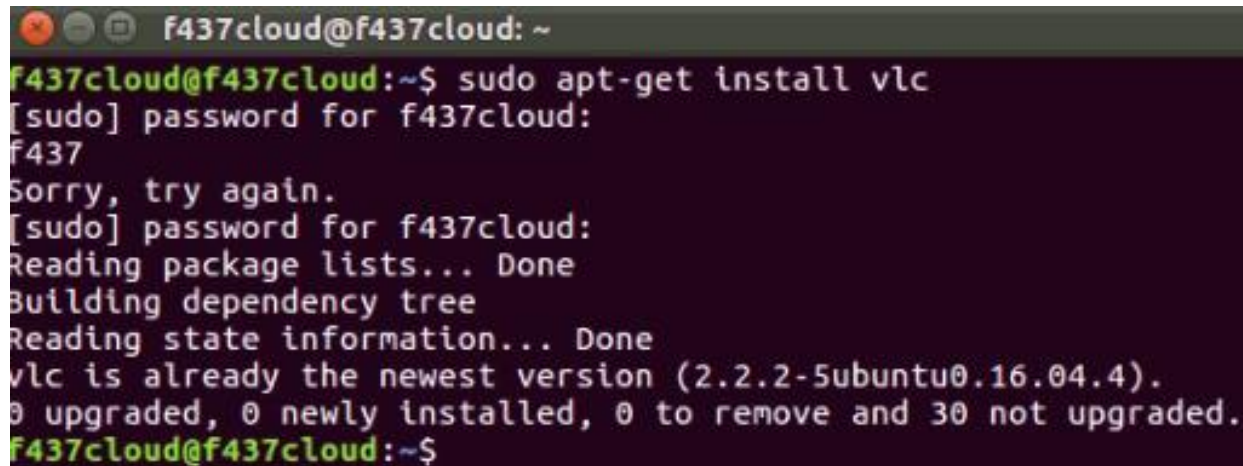
- `cd /usr/local/nginx/sbin`
- `sudo ./nginx -c /usr/local/nginx/conf/nginx.conf`

A terminal window with a dark background and light-colored text. The window title bar shows 'f437cloud@f437cloud: /usr/local/nginx/sbin'. The terminal content shows the user navigating to the nginx sbin directory and running the nginx command with the configuration file path. A password prompt is shown, and the command completes successfully.

```
f437cloud@f437cloud: /usr/local/nginx/sbin
f437cloud@f437cloud:~$ cd /usr/local/nginx/sbin
f437cloud@f437cloud:/usr/local/nginx/sbin$ sudo ./nginx -c /usr/local/nginx/conf/nginx.conf
[sudo] password for f437cloud:
f437cloud@f437cloud:/usr/local/nginx/sbin$
```


使用VLC觀看 (1)

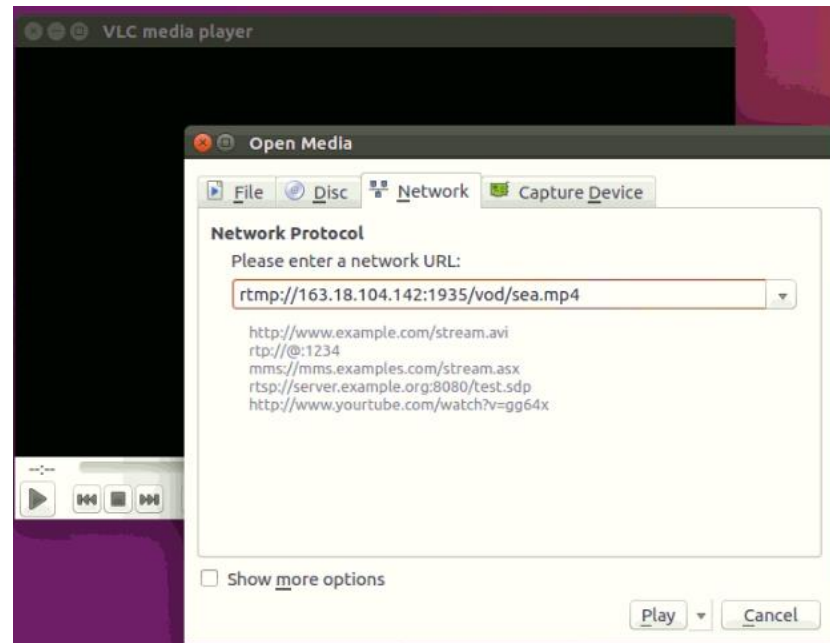
- 安裝VLC
- 在終端機輸入
- `sudo apt-get install vlc`

A terminal window with a dark background and light green text. The window title is 'f437cloud@f437cloud: ~'. The user enters the command 'sudo apt-get install vlc'. The terminal prompts for a password, which is entered as 'f437'. It then says 'Sorry, try again.' and prompts for the password again, which is entered as 'f437cloud'. The terminal then shows the output of the command: 'Reading package lists... Done', 'Building dependency tree', 'Reading state information... Done', 'vlc is already the newest version (2.2.2-5ubuntu0.16.04.4).', and '0 upgraded, 0 newly installed, 0 to remove and 30 not upgraded.' The prompt returns to 'f437cloud@f437cloud:~\$'.

```
f437cloud@f437cloud: ~  
f437cloud@f437cloud:~$ sudo apt-get install vlc  
[sudo] password for f437cloud:  
f437  
Sorry, try again.  
[sudo] password for f437cloud:  
f437cloud  
Reading package lists... Done  
Building dependency tree  
Reading state information... Done  
vlc is already the newest version (2.2.2-5ubuntu0.16.04.4).  
0 upgraded, 0 newly installed, 0 to remove and 30 not upgraded.  
f437cloud@f437cloud:~$
```

使用 VLC 觀看 (2)

- 開啟 VLC，輸入cloudserver影片位址，測試是否能成功觀看
- rtmp://163.18.104.142:1935/vod/sea.mp4 選擇的影片



使用VLC觀看 (3)

- VLC成功觀看畫面



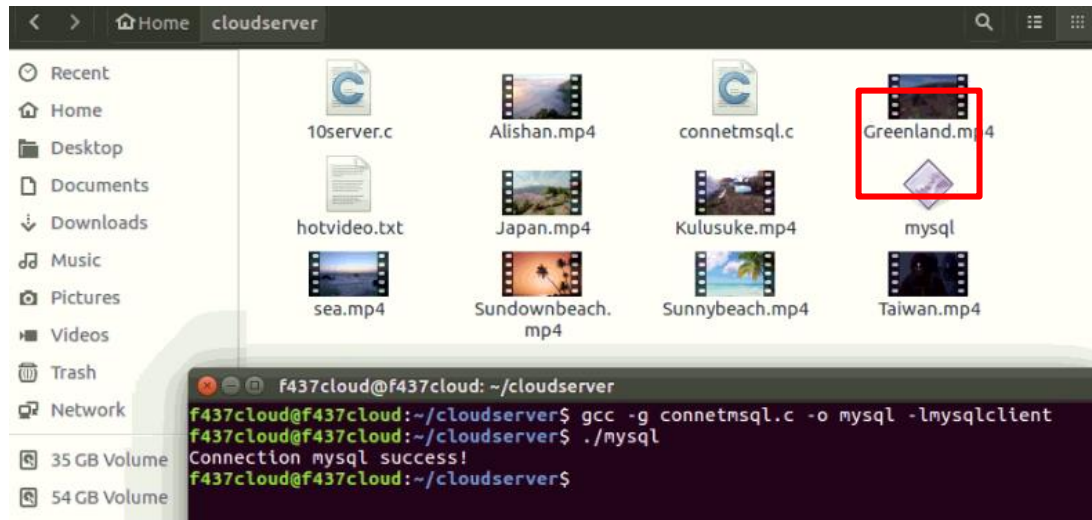
修改 connetmysql.c 程式碼

- 將mysql_real_connect函式
- 更改IP、使用者、密碼，對應資料庫遠端的設定

```
22 //進行實際連線
23 //引數 conn連線控制代碼, host_mysql所在的主機或地址, user使用者名稱, passwd密碼, database_name資料庫名, 後面的都是預設
24 conn = mysql_real_connect(conn, "163.18.104.126", "root", "rootf437", "hotvideo", 0, NULL, 0);
25 if (conn) {
26 printf("Connection mysql success!\n");
27 } else {
28 printf("Connection failed!\n");
29 }
30 mysql_query(conn, "set names gbk");//防止亂碼。設定和資料庫的編碼一致就不會亂碼
31 res = mysql_query(conn, sql);//正確返回0
32 if (res) {
33 perror("my_query");
```

編譯 connetmysql.c

- 編譯connetmysql.c，並產生mysql執行檔
- 在終端機輸入
- `gcc -g connetmysql.c -o mysql -lmysqlclient`
- 執行./mysql時出現Connection mysql success!，代表成功
※要開啟Web Server才能成功連線



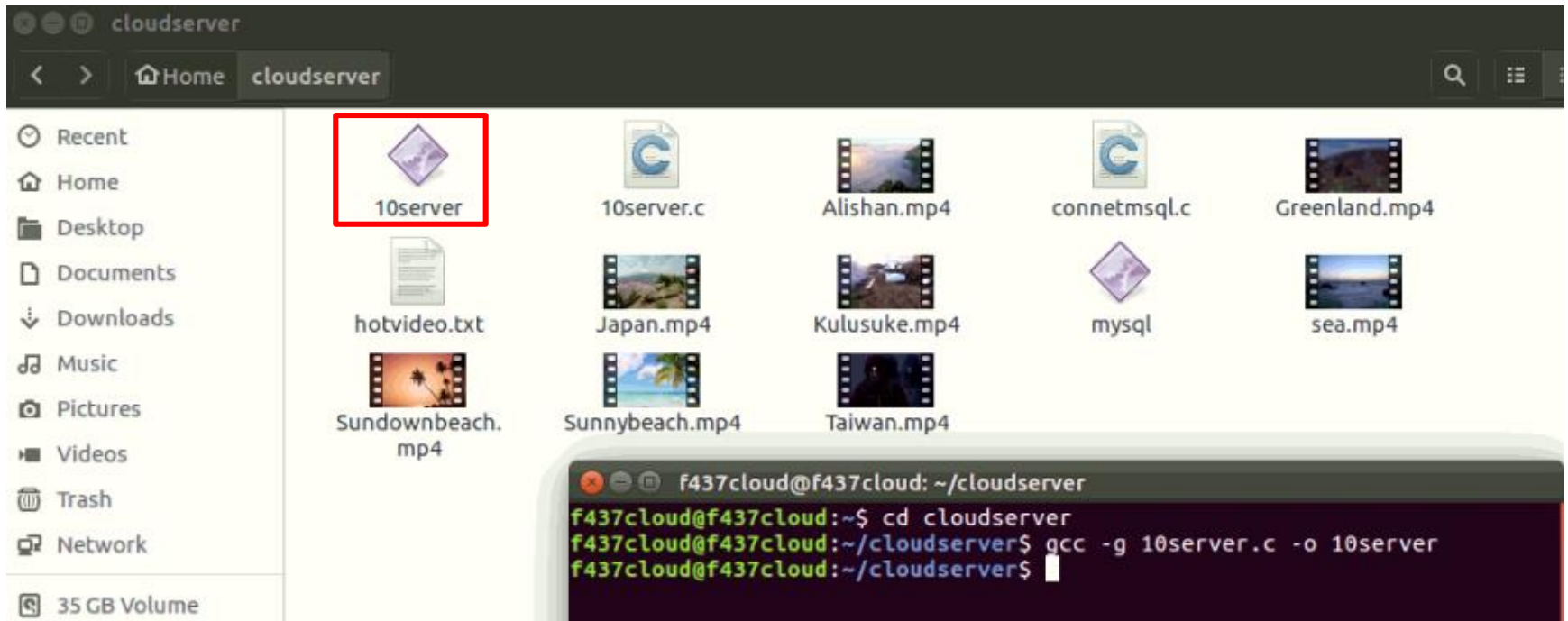
修改 10server.c 程式碼

- 更改成自己的mysql執行檔的路徑

```
85         else{
86             system("/home/f437cloud/cloudserver/mysql");
87             fpr=fopen("hotvideo.txt","r");
88             for(int i=0;i<4;i++)
89             {
90                 fscanf(fpr,"%d",&input);
91                 update[i]=input;
92                 totalsize=totalsize+file_size2(file[input].name);
93             }
94             fclose(fpr);
95         }
```

編譯 10server.c

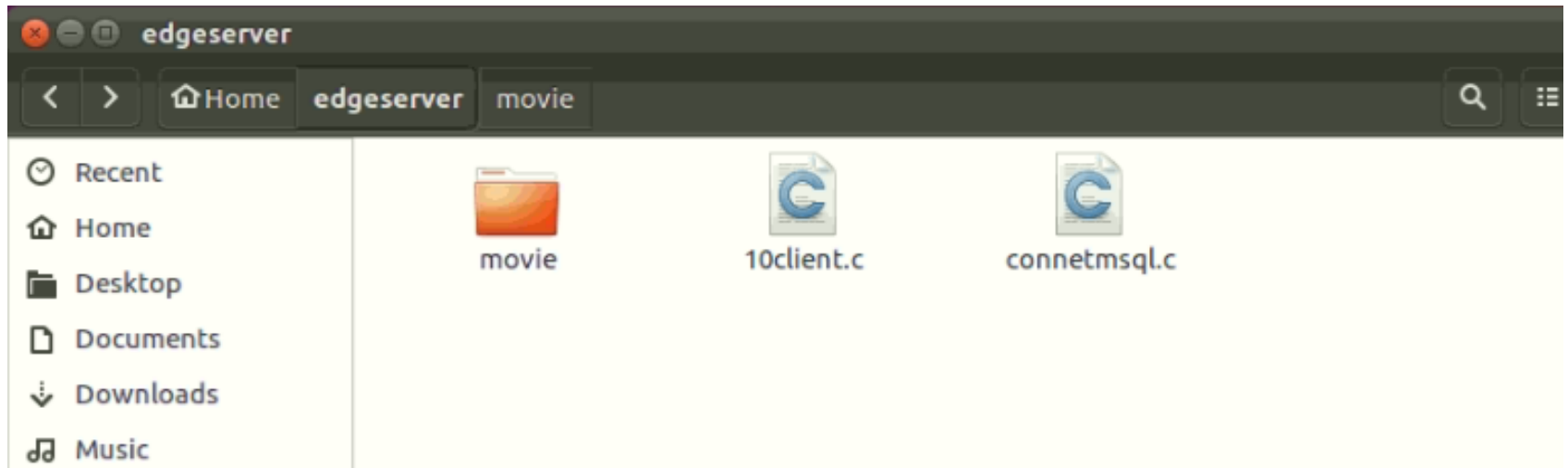
- 在終端機輸入
- `gcc -g 10server.c -o 10server`



Edge Server 安裝

Edge Server 程式下載

- 將edgeserver.zip下載，解壓縮後放到home目錄下
- 網址：<https://drive.google.com/drive/folders/1RJ7cxJgYCAKWl58kR-qxVLkhW8TsXNiM?usp=sharing>



設定nginx

- 在終端機輸入
`sudo gedit /usr/local/nginx/conf/nginx.conf`
- 將程式碼更改成下圖



```
worker_processes 2;
events {
    worker_connections 1024;
}
rtmp {
    server {
        listen 1935;
        chunk_size 4000;

        application myapp {
            live on;
        }

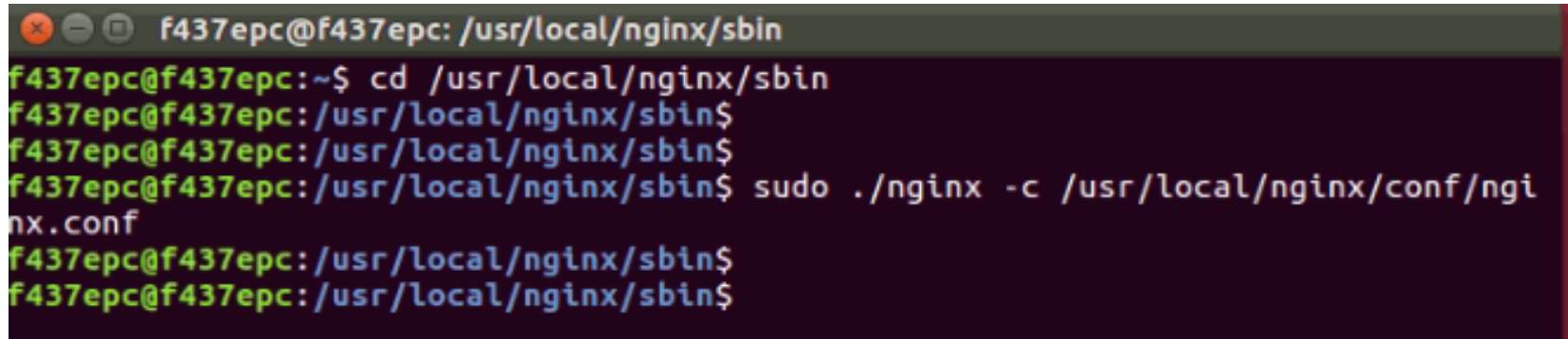
        application vod {
            play /home/f437epc/edgeserver/movie
        }
    }
}
```

Edge Server影片播放位置

開啟nginx

在終端機輸入

- `cd /usr/local/nginx/sbin`
- `sudo ./nginx -c /usr/local/nginx/conf/nginx.conf`

A terminal window with a dark background and light-colored text. The window title bar shows 'f437epc@f437epc: /usr/local/nginx/sbin'. The terminal content shows a series of commands and their outputs. The first command is 'cd /usr/local/nginx/sbin', which changes the directory. The second command is 'sudo ./nginx -c /usr/local/nginx/conf/nginx.conf', which starts the nginx service. The prompt changes from '~\$' to '/usr/local/nginx/sbin\$' after the first command, and from '\$' to '#\$' after the second command.

```
f437epc@f437epc: /usr/local/nginx/sbin
f437epc@f437epc:~$ cd /usr/local/nginx/sbin
f437epc@f437epc:/usr/local/nginx/sbin$
f437epc@f437epc:/usr/local/nginx/sbin$
f437epc@f437epc:/usr/local/nginx/sbin$ sudo ./nginx -c /usr/local/nginx/conf/ngi
nx.conf
f437epc@f437epc:/usr/local/nginx/sbin$
f437epc@f437epc:/usr/local/nginx/sbin$
```

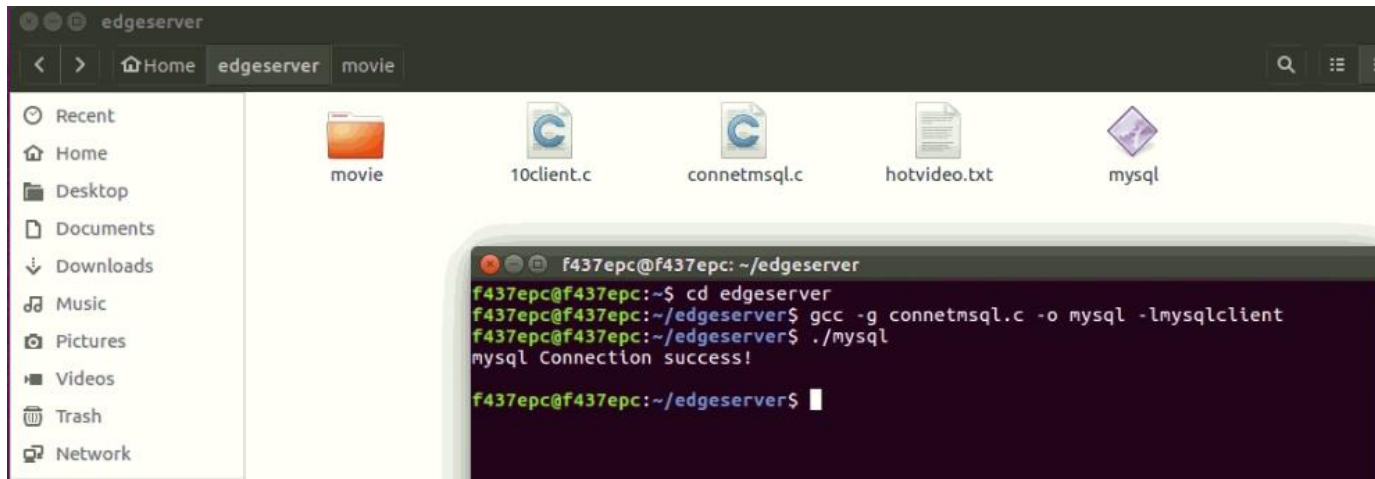
修改 connetmysql.c 程式碼

- 將mysql_real_connect函式
- 更改IP、使用者、密碼，對應資料庫遠端的設定

```
//進行實際連線
//引數 conn連線控制代碼, host mysql所在的主機或地址, user使用者名稱, passwd密碼, database_name資料庫名, 後面的都是預設
conn = mysql_real_connect(conn, "163.18.104.126", "root", "rootf437", "hotvideo", 0, NULL, 0);
if (conn) {
    //printf("mysql Connection success!\n");
} else {
    printf("Connection failed!\n");
}
```

編譯 connetmysql.c

- 編譯connetmysql.c，並產生mysql執行檔
- 在終端機輸入
- `gcc -g connetmysql.c -o mysql -lmysqlclient`
- 執行./mysql時出現mysql Connection success!，代表成功
※要開啟Web Server才能成功連線



修改 10client.c 程式碼 (1)

- 將46行和174的IP更改成Cloud Server IP

```
42  
43 // Filling server information  
44 servaddr.sin_family = AF_INET;  
45 servaddr.sin_port = htons(PORT);  
46 servaddr.sin_addr.s_addr = inet_addr("163.18.104.142");  
47
```

```
172 bzero(&addr, sizeof(addr));  
173 addr.sin_family = AF_INET;  
174 addr.sin_addr.s_addr = inet_addr("163.18.104.142");  
175 addr.sin_port = htons(8181);  
176 len = sizeof(addr);  
177
```

修改 10client.c 程式碼 (2)

- 更改成自己的mysql執行檔的路徑

```
83     unsigned short data_offset=0,num_of_movie=0,count=0;//16bits
84     //-----check movie-----
85     system("/home/f437epc/edgeserver/mysql");
86     fpr=fopen("hotvideo.txt","r");
87     for(int i=0;i<4;i++) {
88         fscanf(fpr,"%d",&input);
89         choose_buf[i]=input;
90     }
```

修改 10client.c 程式碼 (3)

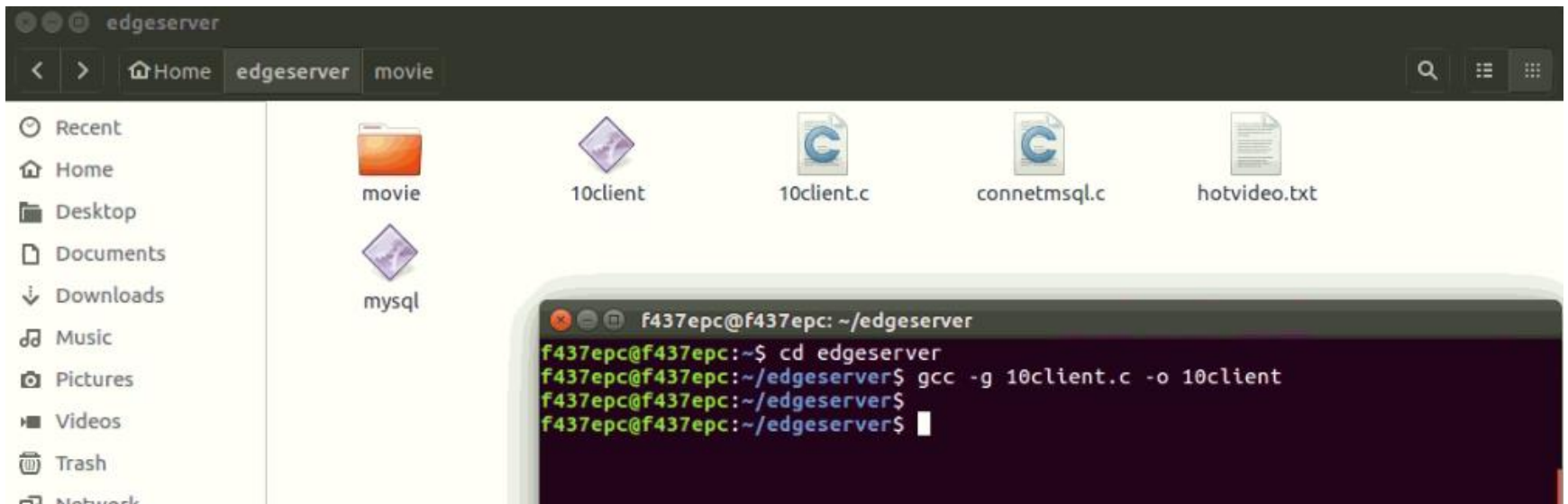
- 修改路徑，將影片移動到movie資料夾

```
216     if (i == s + 1)
217     {
218         printf("-----\n");
219         commd_end(addr, end); //need ot create new function
220         if(reply_buf[0] != 0) { //move to darwin server
221             //system("sudo cp /home/f437epc/edgeserver/*.mp4 /usr/local/movies/");
222             system("mv /home/f437epc/edgeserver/*.mp4 /home/f437epc/edgeserver/movie/");
223         }
224     }
```


編譯 10client.c

在終端機輸入

- `gcc -g 10client.c -o 10client`



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OAI運行(啟動EPC程式)

在終端機輸入

- `cd ~/openair-cn/scripts`
- `./run_hss`

開啟一個新的終端機，並且輸入

- `cd ~/openair-cn/scripts`
- `./run_mme`

開啟一個新的終端機，並且輸入

- `cd ~/openair-cn/scripts`
- `./run_spgw`

OAI運行(啟動eNB程式)

到eNB的電腦上，在終端機輸入

- `$ cd ~/openairinterface5g/cmake_targets/lte_build_oai/build`
- `$ sudo -E ./lte-softmodem -O ~/openairinterface5g/targets/PROJECTS/GENERIC-LTE-EPC/CONF/enb.band7.tm1.usrpb210.conf -d`

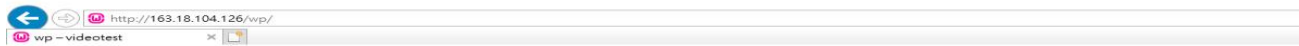
UE註冊

到網頁上輸入192.168.8.1，並開啟LTE網路



Web Server 開啟

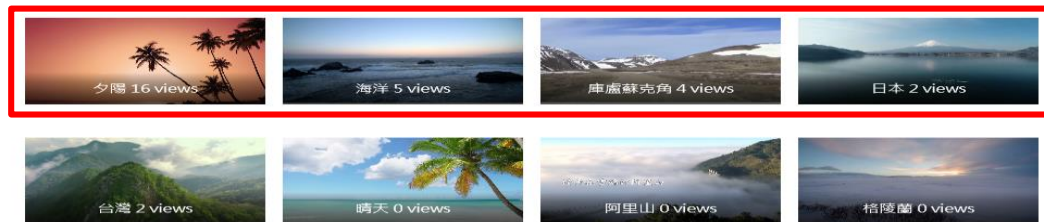
- 將Wampserver64程式開啟
- 進入網頁查看是否開啟
- 輸入：163.18.104.126/wp



wp — videotest

電影目錄(cloud)

前四部熱門影片

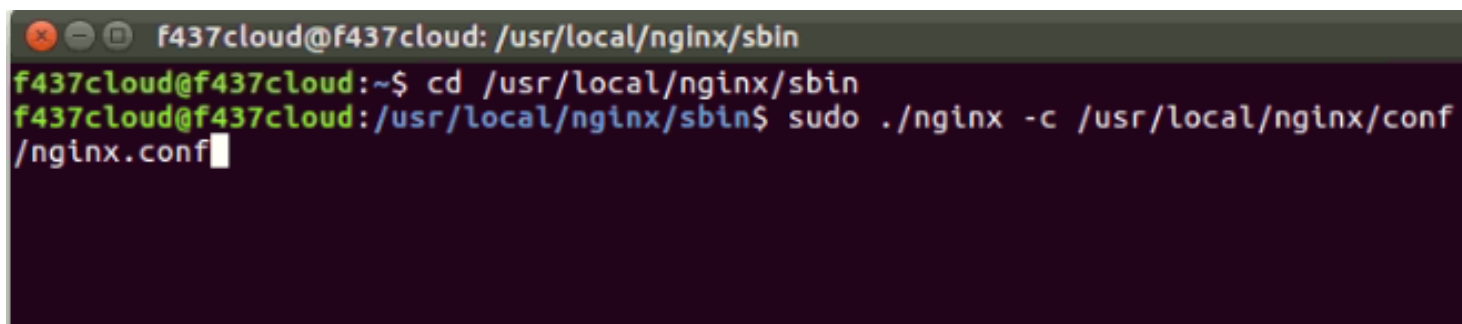


電影目錄(edge)



開啟 Cloud Server 串流

- Cloud Server 開啟影片串流伺服器
- 在終端機輸入
- `cd /usr/local/nginx/sbin`
- `sudo ./nginx -c /usr/local/nginx/conf/nginx.conf`

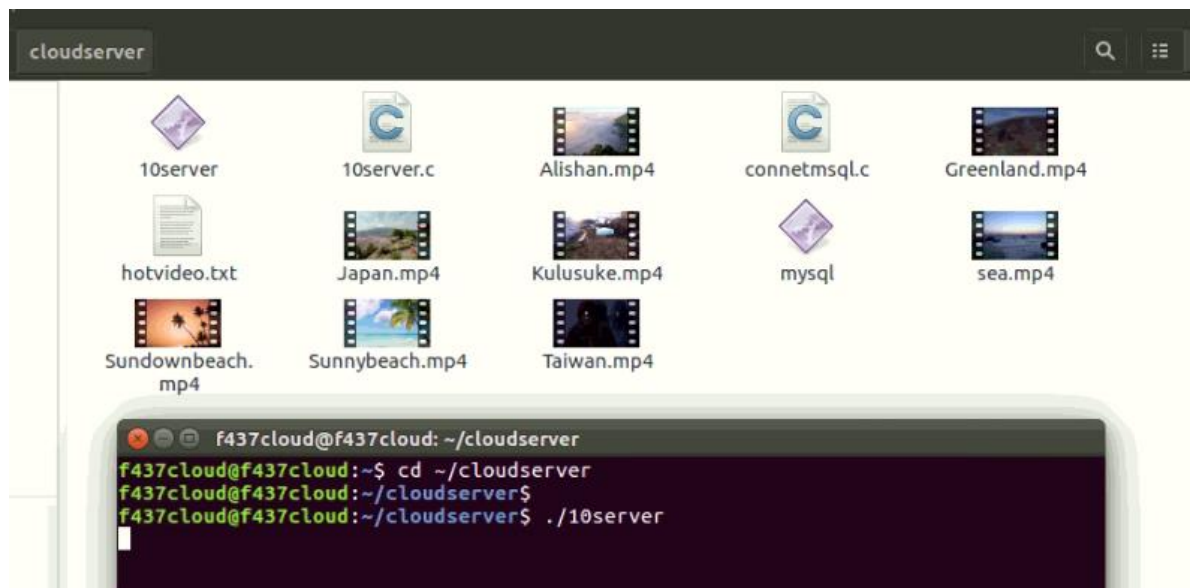


```
f437cloud@f437cloud: /usr/local/nginx/sbin
f437cloud@f437cloud:~$ cd /usr/local/nginx/sbin
f437cloud@f437cloud:/usr/local/nginx/sbin$ sudo ./nginx -c /usr/local/nginx/conf/nginx.conf
```

開啟Cloud Server程式

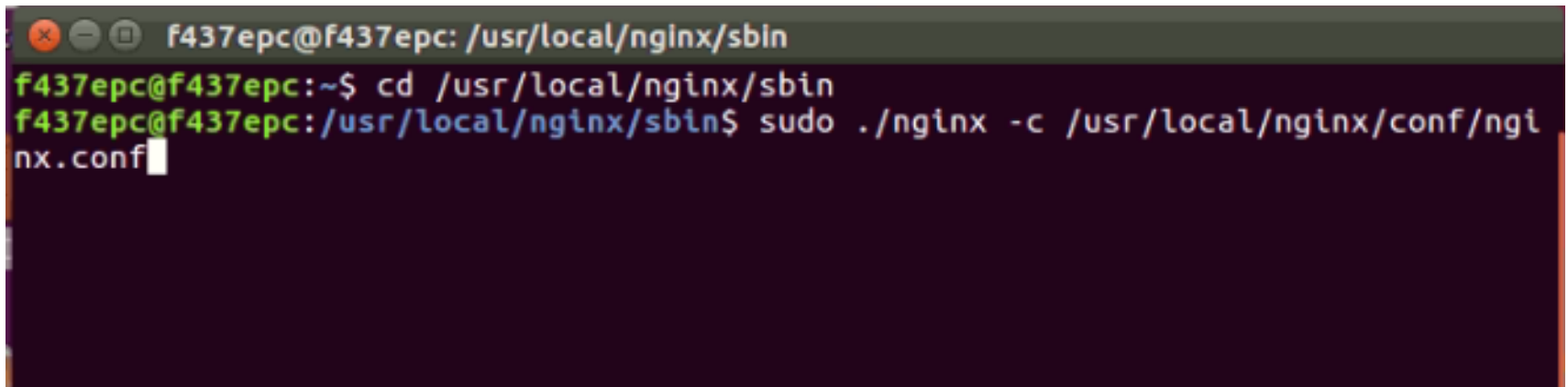
在終端機輸入

- `cd ~/cloudserver`
- `./10server`
- 等待EdgeServer連接



開啟Edge Server串流

- Edge Server開啟影片串流伺服器
- 在終端機輸入
- `cd /usr/local/nginx/sbin`
- `sudo ./nginx -c /usr/local/nginx/conf/nginx.conf`

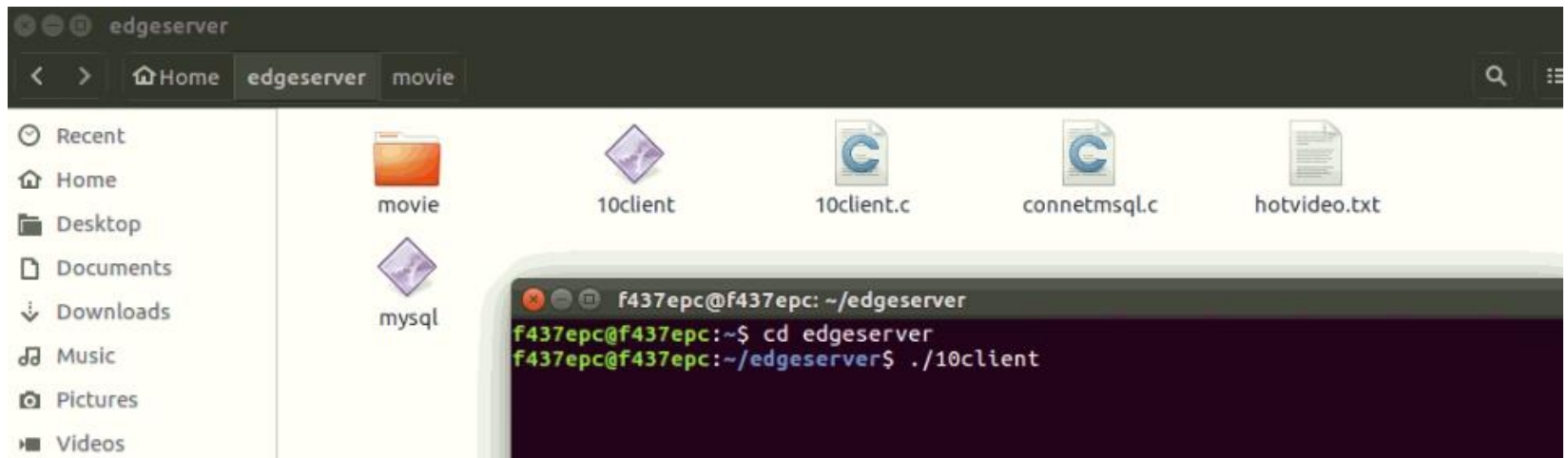


```
f437epc@f437epc: /usr/local/nginx/sbin
f437epc@f437epc:~$ cd /usr/local/nginx/sbin
f437epc@f437epc:/usr/local/nginx/sbin$ sudo ./nginx -c /usr/local/nginx/conf/ngi
nx.conf
```

開啟Edge Server程式

在終端機輸入

- `cd ~/edgeserver`
- `./10client`



Edge Server畫面

- Edge Server跟Cloud Server要求取得前四部熱門影片

```
f437epc@f437epc: ~/edgeserver
f437epc@f437epc:~$ cd edgeserver
f437epc@f437epc:~/edgeserver$ ./10client
First request movies.
Server reply :total movie size = 66412 kB
Server reply movie NO.23
Server reply movie NO.29
Server reply movie NO.57
Server reply movie NO.45
ftp>edge[ get 23 ]
ftp>edge[ get 29 ]
ftp>edge[ get 57 ]
ftp>edge[ get 45 ]
-----
after 10 second
mysql Connection success!

edge have had same movies
-----
```

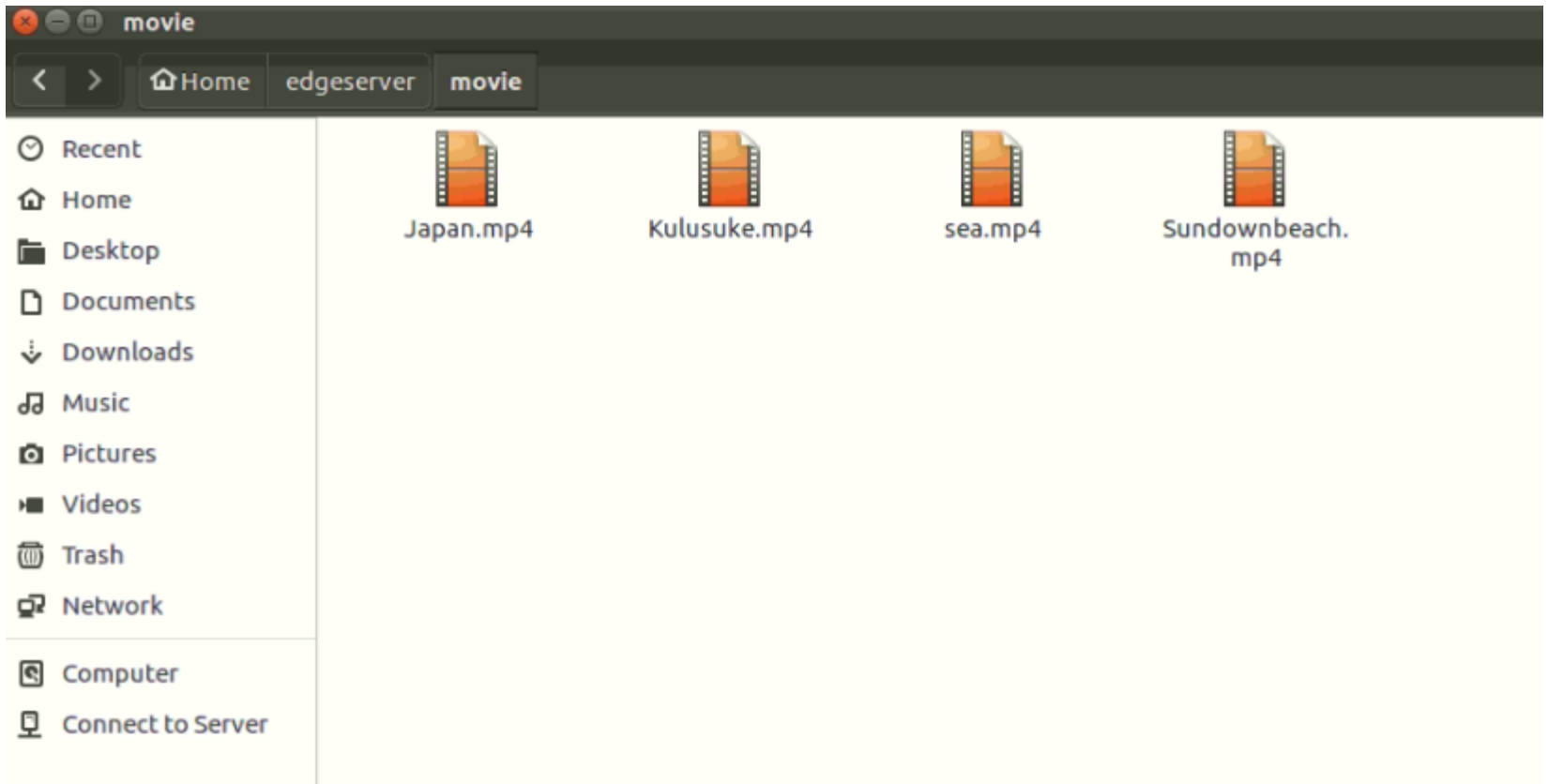
Cloud Server畫面

- Cloud Server正在將熱門影片傳送影片給Edge Server

```
f437cloud@f437cloud: ~/cloudserver
f437cloud@f437cloud:~$ cd cloudserver
f437cloud@f437cloud:~/cloudserver$ ./10server
Connection mysql success!
edge server request 4 movies
send reply.
cloud_ftp>rcvd [ get 23 ]
get filename : [ Sundownbeach.mp4 ]
cloud_ftp>rcvd [ get 29 ]
get filename : [ sea.mp4 ]
cloud_ftp>rcvd [ get 57 ]
get filename : [ Kulusuke.mp4 ]
cloud_ftp>rcvd [ get 45 ]
get filename : [ Japan.mp4 ]
cloud_ftp>rcvd [ end ]
-----
--
Connection mysql success!
edge server request 0 movies
send reply.
cloud_ftp>rcvd [ end ]
-----
--
```

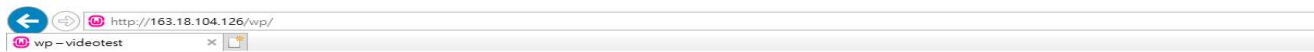
Edge Server 取得熱門影片

- Edge Server 取得熱門影片



UE端觀看影片(1)

- UE端 開啟IE，輸入網址：163.18.104.126/wp
- 可觀看Edge Server和Cloud Server的影片



wp — videotest

電影目錄(cloud)

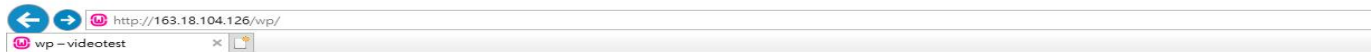


電影目錄(edge)



UE端觀看影片(2)

- 點擊觀看台灣影片，讓它變成熱門影片



wp — videotest

電影目錄(cloud)

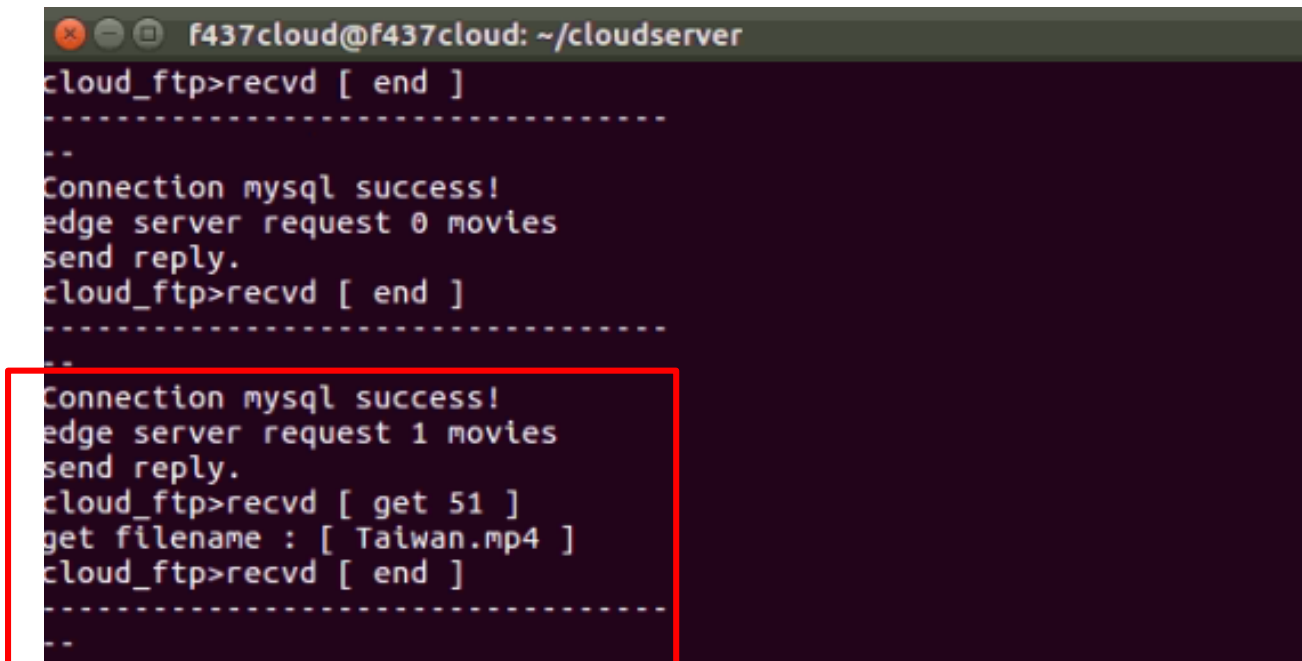


電影目錄(edge)



UE端觀看影片(3)

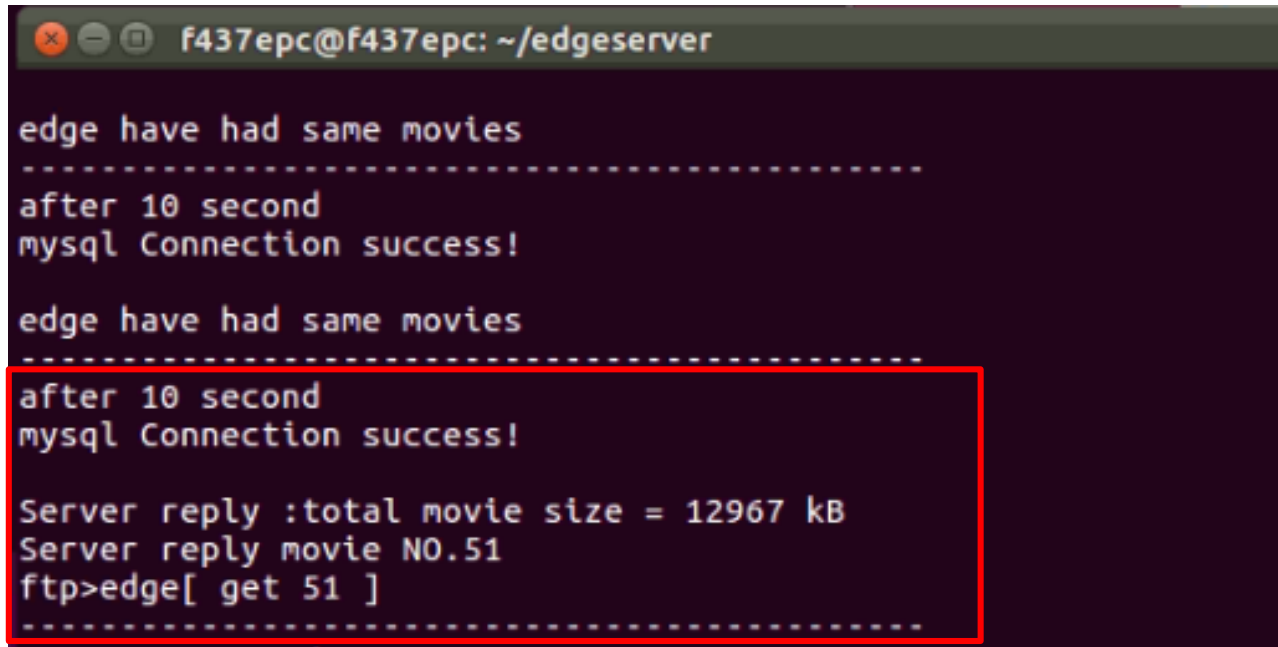
- Cloud Server會把台灣影片傳送給Edge Server

A terminal window with a dark background and light-colored text. The title bar shows 'f437cloud@f437cloud: ~/cloudserver'. The terminal output shows a sequence of commands and responses. A red rectangular box highlights a specific section of the log. The text inside the box is: 'Connection mysql success!', 'edge server request 1 movies', 'send reply.', 'cloud_ftp>recv [get 51]', 'get filename : [Taiwan.mp4]', and 'cloud_ftp>recv [end]'. The text outside the box includes: 'cloud_ftp>recv [end]', '-----', '--', 'Connection mysql success!', 'edge server request 0 movies', 'send reply.', 'cloud_ftp>recv [end]', '-----', '--', and 'Connection mysql success!'.

```
f437cloud@f437cloud: ~/cloudserver
cloud_ftp>recv [ end ]
-----
--
Connection mysql success!
edge server request 0 movies
send reply.
cloud_ftp>recv [ end ]
-----
--
Connection mysql success!
edge server request 1 movies
send reply.
cloud_ftp>recv [ get 51 ]
get filename : [ Taiwan.mp4 ]
cloud_ftp>recv [ end ]
-----
--
```


UE端觀看影片(4)

- Edge Server接收影片

A terminal window with a dark background and light-colored text. The window title bar shows 'f437epc@f437epc: ~/edgeserver'. The terminal output consists of several lines of text, with a red rectangular box highlighting a specific section. The text includes status messages, a 10-second delay, a successful MySQL connection, and server response details about movie size and ID.

```
f437epc@f437epc: ~/edgeserver

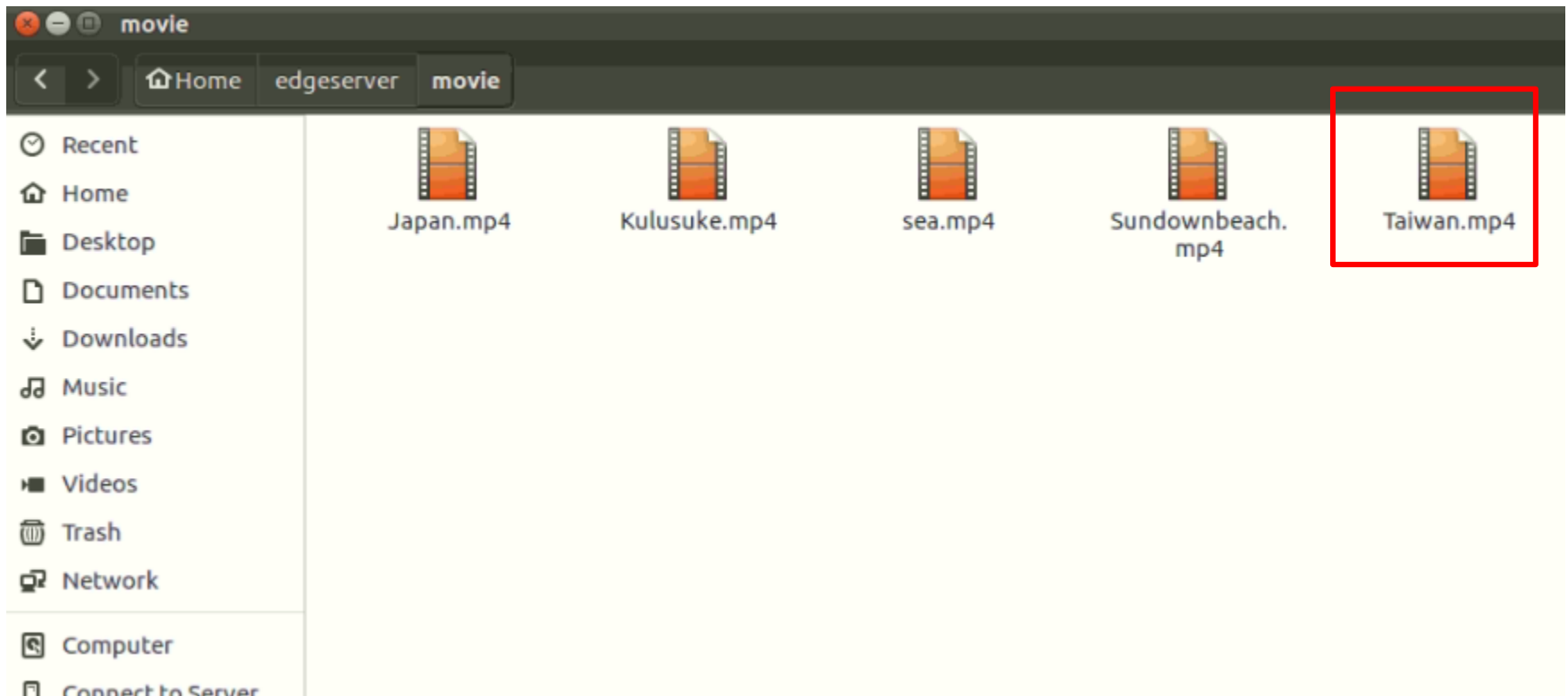
edge have had same movies
-----
after 10 second
mysql Connection success!

edge have had same movies
-----
after 10 second
mysql Connection success!

Server reply :total movie size = 12967 kB
Server reply movie NO.51
ftp>edge[ get 51 ]
-----
```

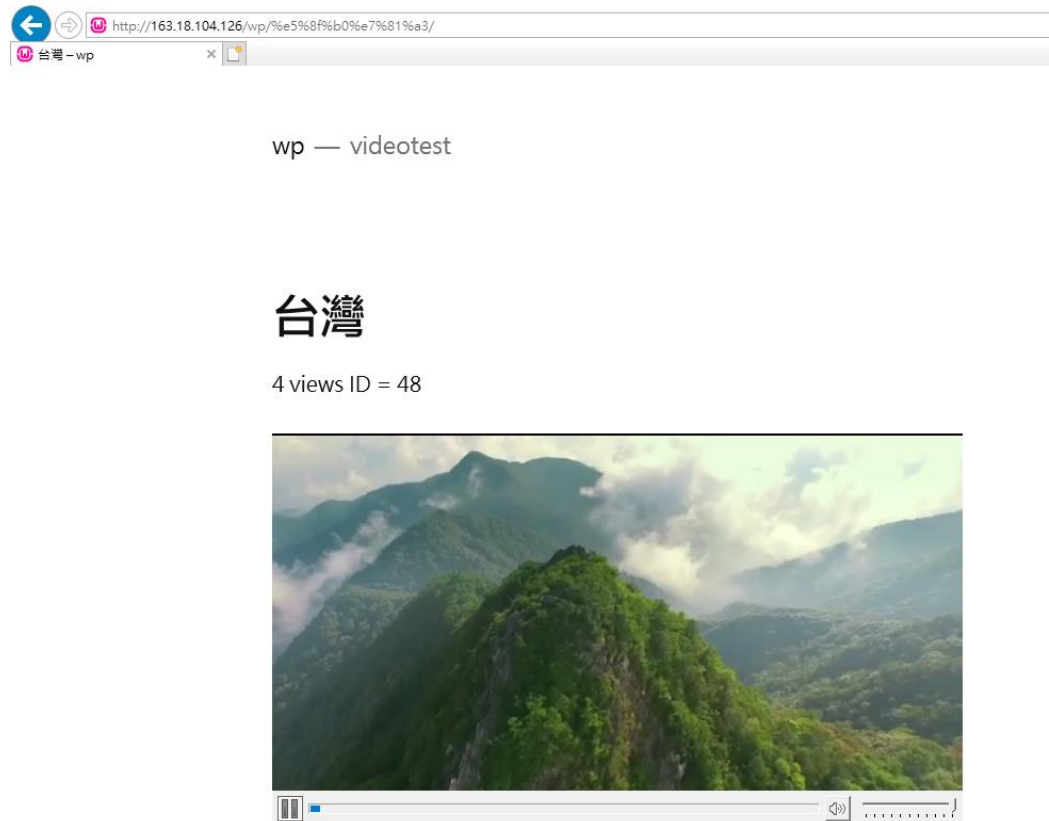
UE端觀看影片(5)

- Edge Server影片存放資料夾



UE端觀看影片(6)

- Edge Server的台灣影片觀賞

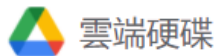


Outline

- 實驗目的及實驗內容
- 實驗環境
- 平台安裝需求
- Cloud與Edge伺服器的通訊協定
- Cloud、Edge程式碼修改
- VoD Streaming資料串流實驗執行
- 附錄

程式碼下載處

- Web Server、Cloud Server與Edge Server下載處
- 網址：<https://drive.google.com/drive/folders/1RJ7cxJgYCAKW158kR-qxVLkhW8TsXNiM?usp=sharing>



MEC_實驗二_程式碼

檔案

